PATENT SPECIFICATION

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(21) Application No. 41535/75 (22) Filed 10 Oct. 1975
(31) Convention Application No. 7436208
(32) Filed 30 Oct. 1974 in
(33) France (FR)
(44) Complete Specification published 26 July 1978
(51) INT CL² B29D 3/00
(52) Index at acceptance
B5A 1R159 1R214D 1R214F 1R314C1S 1R415 1R447 20T1 20T9 B11

(19) THE PATENT OFFICE LONDON

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(54) IMPROVEMENTS IN OR RELATING TO COMPOSITE MATERIALS

(71) We, SOCIETE NATIONALE D'ETUDE ET DE CONSTRUCTION DE MOTEURS D'AVIATION, a French Body Corporate, of 150, boulevard Haussmann, 75008 Paris, France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to methods of manufacturing articles or parts of articles from composite materials, and to such articles or parts of articles *per se*.

Composite materials have been proposed which are formed by the juxtaposition and/or the association of materials having different physical and mechanical properties. Furthermore, the manufacture of compressor and fan blades has been proposed utilizing material constituted by orientated fibres held together by a matrix of material, such composite materials having variable compositions according to their position in the body of the blades. Metallic articles are likewise known of which the surface is modified by various treatments and which, for this reason may be considered to be manufactured of a composite material.

According to the present invention there is provided a method of producing an article of composite material, comprising the steps of placing in two semi-moulds oriented fibres in a resinous matrix forming superficial material of the completed article, placing in the moulds a pre-formed core of randomly-dispersed fibres in a resinous matrix capable of copolymerising with the resin of the superficial material, assembling together the two parts of the mould and heating the assembly to a temperature sufficient to polymerise the resin or resins used.

Further according to the present invention there is provided a method of producing an article of a composite material comprising the steps of depositing in two semi-moulds pre-formed orientated fibres in a resinous matrix of the superficial material, filling the remaining space in the mould with a pre-formed core of randomly-orientated fibrous material in a resinous matrix capable of co-polymerising with the resin of the superficial material, assembling the semi-moulds and raising the temperature of the materials therein to polymerisation temperature of the resin or resins.

The term "specific modulus of elasticity" signifies herein the modulus of elasticity in bending (expressed in Hecto bars—h bars) for unitary density of the material considered.

It is possible to use for making the pre-formed core and the superficial material of the composite material in accordance with the invention, the same fibres which may be glass fibres of E or S quality or carbon fibres or other high strength fibres, but it is not necessary that these fibres should be the same in the material of the core and in the superficial material. In practice, it is preferred to use, for the pre-formed core, glass fibres and for the superficial material fibres with orientated crystallisation having high mechanical strength. The essential difference between the material constituting the core and the superficial material resides in the orientation of the fibres, this orientation having been provided only in the superficial material; for the latter it will therefore be preferred to use fibres in the form of felt or cloth.

As the matrices known resins may be used both for the core and for the superficial material, provided that the resins of the one and of the other of these materials are compatible, that is to say capable of forming a rigid connection by concurrent polymerisation. For preference pre-polymerised resins are therefore used which will be fully reacted during the fabrication of the

composite material and preferably polyimide resins will be used.

In accordance with the invention components of the composite material may be, for example:

For the pre-formed core pre-mixes of glass fibres and polyimide resin (50% by volume of glass fibres) having the following properties:

Modulus of elasticity in bending 1,900—2,500 h bars
Load at fracture in flexing 35—40 h bars
Density (g/cm.^{3}) 1.9.

Alternatively a pre-mix of carbon fibres and polyamide resin (50% by volume of carbon fibre) having the following property may be used:

Modulus of elasticity in bending 4,000—6,000 h bars
Loads at fracture in bending 30—35 h bars
Density (g/cm.^{3}) 1.55

For the superficial material felts of carbon fibre with undirectional orientation and polyimide resin (55% by volume of fibres) have the following properties:

	High Modulus Type	High Strength Type
Modulus of elasticity in bending in (h bars)	14,000—16,000	8,000—10,000
Load at fracture in bending (h bars)	50—60	90—100
Shear strength between adjacent supports (h bars)	4—5	8—9
Density (g/cm.^{3})	1.64	1.50

High modulus and high strength fibres are available commercially. High modulus fibres are, in general, in the form of graphite with a high degree of orientation of the fibres, whilst high strength fibres, produced, for example by pyrolysis, have an amorphous form. Boron fibres are of high modulus type and glass fibres are of high strength type.

For material which constitutes the core of the composite product, preforming aims to distribute the material as a function of the final thickness of the various parts of the article and to achieve a degree of orientation of the fibre assembly contained in this material so as to produce fibre distribution analogous to that obtained in the operation of forging or stamping. An excessive flow of the surface material during the final pressing operation is avoided by preforming the core.

In accordance with the methods hereinbefore described, composite materials can be produced of which the following are examples:

Example 1

A composite material is prepared comprising a core constituted by a pre-mix of glass fibres and of polyimide resin in which the volume of glass fibres is 75%, and a superficial part constituted by a felt of carbon fibres and by a polyimide resin, the felt representing approximately 25% by volume of this part.

The composite material has a thickness of about 4 mm. and the pre-formed core has a thickness of about 3 mm.

This example produces articles having the following properties:

	High modulus Type	High Strength Type
Modulus of elasticity (h bars)	9,500—11,000	5,000—6,500
Load at fracture in bending (h bars)	35—40	50—60
Density (g/cm.^{3})	1.80	1.76

Example 2

A composite material is prepared comprising a pre-formed core constituted by a pre-mix of glass fibres and of polyimide resin in which the volume of glass fibres in 50%, and a superficial part constituted by a carbon fibre felt and by a polyimide resin, the felt representing 50% by volume. ...The composite material has a thickness of about 20 mm., the core representing approximately 15mm. of this thickness.

Articles in accordance with this example have the following properties:

	High Modulus Type	High Strength Type
Modulus of elasticity in bend (h bar)	12,000—14,000	6,500—8,000
Load at fracture in bend bend (h bar)	40—45	70—80
Density (g/cm.^{3})	1.75	1.67

Example 3

Test pieces were made constituted with a pre-formed core of a mixture of glass fibres and polyimide resin (volume of fibres 60%), the core lying between two superficial layers of composite fibres of orientated boron and of polyimide resin (volume of fibres 60%).

The total thickness of each test piece was 3 mm. and the thickness of the core was varied between 0.6 and 2.4 mm; the composite material thus obtained had specific modulii in bending as follows:

(mm.)	Specific modulus in bending (h bars)
0.6	14,450
1.2	13,790
2.3	11,300
2.4	7,900

The composite material in accordance with the invention and methods of preparation of such materials is particularly convenient for the manufacture of various parts namely: flow distribution casings for turbo machines, blade-retaining rings, cold fluid guide vane assemblies and wheel rims.

There is described hereinafter, by way of example, the manufacture of a vane of a guide vane assembly.

Examples 4

Manufacture of a compressor vane.

For a member of this kind, it is desirable to raise the natural frequency of the vane and to dispose the high strength fibres mechanically as far as is possible from the neutral fibre of the vane.

There is placed in two moulds, one for the undersurface (or intrados), the other for the outer surface (or extrados) layers of orientated fibres in accordance with the required characteristics (composite material with high modulus strength characteristics). Then, on the internal face of one or other of the moulds filling material is deposited which comprises fibres having a length of from 6 to 12 mm. This filling material which transmits and distributes the pressures between the two external parts is constituted by a pre-formed core and should have a polymerisation time conveniently close to that of the layers of high modulus.

The thickness of the core which has been pre-formed is almost uniform and is approximately 15 mm. It is advantageous to give it a form enabling the fibres to migrate from the leading and trailing edges without becoming disorientated. After passage through a press, the thickness will vary according to the section considered between 5 and 6 mm. for the leading edge and trailing edge and 13 mm. at the centre.

The two moulds are then superposed and placed in the press.

Polymerisation is carried out in the press at 230°C under a pressure of 250 to 300 bars.

A finished part is thus produced in about 10 minutes. For more economic industrial manufacture the moulds can be associated in clusters in a common press and heated together.

The method in accordance with the invention enables the production of various thicknesses imposed by the geometry of the article much more readily than by hitherto proposed methods which involve superimposing a large number of layers of fibres cut to conform to the designed variation of the profile of the vane, blade or other article.

In the case of a vane of a compressor or blower or other fluid flow deflecting machine, the leading edge and the trailing edge are produced by the flow under pressure of the fill material, constituting the pre-formed core, which fills the spaces left free at the leading edges and trailing edges between the pre-formed core, the skin and the mould.

WHAT WE CLAIM IS:—

1. A method of producing an article of composite material, comprising the steps of placing in two semi-moulds orientated fibres in a resinous matrix forming superficial material of the completed articles, placing in the moulds a pre-formed core of randomly-dispersed fibres in a resinous matrix capable of copolymerising with the resin of the superficial material, assembling together the two parts of the mould and heating the assembly to a temperature sufficient to polymerise the resin or resins used.

2. A method of producing an article of a composite material comprising the steps of depositing in two semi-moulds pre-formed orientated fibres in a resinous matrix of the superficial material, filling the remaining space in the mould with a pre-formed core of randomly-orientated fibrous material in a resinous matrix capable of copolymerising

with the resin of the superficial material, assembling the semi-moulds and raising the temperature of the materials therein to polymerisation temperature of the resin or resins.

3. A method according to claim 1 or claim 2 wherein the material constituting the core has a specific modulus of elasticity lying between 1,000 and 4,000 h bars, and the said superficial material has a specific modulus of elasticity lying between 5,000 and 20,000 h bars.

4. A method according to any one of claims 1 to 3 wherein the orientated fibres of the superficial material are in the form of felt or of cloth.

5. A method according to any one of the preceding claims wherein the resins are polyimides.

6. Finished articles such as guide vane assemblies and wheel rims manufactured by the method according to any one of the preceding claims.

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Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1978
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.